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GYPSUM: ITS USES AND PREPARATION

BY

R. M. SANTMYERS

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

GYPSUM: ITS USES AND PREPARATION[1]

By R. M. Santmyers[2]

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INTRODUCTION

Gypsum is one of the important nonmetallic minerals commonly used in building construction, but its other uses extend over a wide field; in the arts, in the plate glass and jewelry industry; as a filler in paint and paper; for confectionery molds, dental and surgical plaster, etc. Chemically, gypsum is a sulphate of calcium and differs from anhydrite, which has a similar composition, in that it crystallizes in nature with 2 molecules of water, corresponding to the formula, $CaSO_4.2H_2O$. When pure it contains 79.1 per cent of calcium sulphate and 20.0 per cent of water.

In the form of a manufactured powder, free from any trace of color, gypsum is known as "mineral white" or "terra alba." The chief demand for this material is in the paper trade, in which it is employed as a filler. It is also used extensively for finishing cotton and lace goods and to a small extent as a substitute for lead compounds and barites in the manufacture of paint.

When ground, but otherwise untreated, gypsum is used as a fertilizer, either by direct application to the soil or in alternate layers with manure. Stored in this manner, manure is said to lose only 2 per cent of its ammonia content in five or six months. Gypsum is also mixed with chemical fertilizers as a diluent to reduce the percentage of superphosphates.

Ground gypsum is also used as a retarder in the manufacture of Portland cement. In the United States and other countries except England and Germany the amount allowed is 3 per cent, while in these last two countries 2 per cent is permitted. Crude gypsum has been used to a limited extent as a source of sulphur in smelting ores, (notably New Caledonian nickel ores), while a very low grade of gypsum is used to polish tin plate.

When heated to about 130° C. gypsum loses a portion of its water of crystallization, and the product forms the quick-setting cement known as "plaster of Paris," a term which was applied to calcined gypsum because it was mined in large quantities in the Tertiary deposits at Montmartre in the Paris basin, France. In addition to the ordinary uses of plaster of Paris for building it is employed extensively in the manufacture of molds, in modeling, and in the marble-working and lithographic trades. Very pure plaster of Paris is used in dentistry, and this dental plaster commands a high price, as does that used in orthopedic surgery, chiefly as a filler for bandages.

When heated to higher temperatures gypsum becomes practically anhydrous. This product, if not heated too strongly, retains the power of setting and reverts to the hydrated form. Anhydrous or practically anhydrous sulphate of lime, obtained by burning gypsum under special conditions, is the basis of various special cements and plasters.

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The writings of Theophrastus and Pliny show that the Greeks were familiar with the uses of plaster in making casts. According to the former, the first plaster casts were made by Lysistratus of Sicyon, who was a brother of the famous sculptor Lysippus. He made first a cast in plaster from the object and from this obtained a second one in wax. Rhaecas and Theodorus of Samos worked by the same method, but the art appears to have attracted very little attention and was soon neglected and in course of time forgotten. It was revived by Verocchio (1422-1488) and others, when the method of casting in plaster proved of great service in obtaining copies of the specimens of ancient sculpture which were then discovered.

The great pyramids of Egypt contain guysum plaster work which was executed at least 4,000 years ago and to-day is still hard and durable.

The alabaster used in these early days came mainly from Syria and upper Egypt. The statues and bas relief of the mausoleum of the Connetable de Lesdiguieres, of the Cathedral of Gap, were carved from alabaster taken from Boscadon near Embrun, in the High Alps. At the present time large quantities are used in Italy for sculpture. Only in the past half century has calcined gypsum had any extensive use, although for several centuries, as noted above, it has been used to a limited extent for plaster and for making casts and statuary.

USE IN THE UNITED STATES

The use of gypsum in the United States dates back about a century and a quarter. The early settlers in their westward movement were the first to use gypsum, practically all in the form of land plaster or fertilizer. Gypsum was discovered in New York as early as 1792, but it was not until exactly a century later, 1892, that the first producttion of plaster of Paris from gypsum mined in the State was reported. In 1882, however, considerable quantities of rock gypsum from Nova Scotia were said to have been used in the manufacture of plaster of Paris in New York. The first use of gypsum in Virginia was in 1835 as land plaster, and about 1840 the deposits near Grand Rapids, Mich., were discovered. It was next utilized in Ohio, near Sandusky, in 1850; in Iowa, in the vicinity of Fort Dodge, in 1872; and in California in 1875. The first mill for the manufacture of gypsum into plaster of Paris was built by George Morrison, at Morrison, Colo., prior to 1875.

In 1875, the Colorado Springs Plaster of Paris Co. erected at Colorado City, Colo., at a cost of $16,000 a plant with a capacity of 15,000 pounds of plaster daily, which was about three times the demand in the State. Practically no plaster was made, however, until 1879, in which year about 300,000 pounds were produced.

Since 1880 the growth of the gypsum industry has been very rapid. During the period 1898 to 1903 the increase in production was more than 350 per cent; it was then that gypsum wall plaster began to be used extensively. Largely as a result of its growing use as a building material the industry has grown in annual output from $750,000 in 1898 to approximately $47,000,000 in 1926 ($32,000,000 in 1928).

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PHYSICAL PROPERTIES

Gypsum has a hardness of 2 to 2.5, based on Moh's scale, and hence can be easily scratched with the finger nail. The specific gravity is 2.3 to 2.4. Approximately average weights of gypsum rock and of plaster of Paris are given in the following table:

Approximate weights of gypsum rock and plaster of Paris

	Weight per cu. ft. lbs.
Gypsum rock (not calcined and dry).....	140-145
Gypsum rock (crushed, not calcined and dry, all to pass 1 in. ring).....	90-100
Gypsum rock (crushed, not calcined and 80 per cent to pass 100-mesh screen).....	75-80
Gypsum rock (ground and calcined 80 per cent to pass 100-mesh screen)..Loose..	55-65
..Shaken.	65-75
Plaster of Paris (rehydrated and dry).....	72-77

SOLUBILITY

Gypsum is sparingly soluble in water. At 32° F. 415 parts of water dissolves 1 part of gypsum. The maximum solubility is reached at 100° F., and even then 368 parts of water are needed to dissolve 1 part of gypsum. The following table shows the solubility of gypsum and anhydrous sulphate of lime at different temperatures: -

Temperature	One part of gypsum dissolves in	One part of anhydrous sulphate lime dissolves in
at 32.0° F. - 0°C.	415 parts of water	525 parts of water
64.5° F. - 18° C.	386 parts of water	438 parts of water
75.2° F. - 24° C.	378 parts of water	479 parts of water
89.6° F. - 32° C.	371 parts of water	470 parts of water
100.4° F. - 38° C.	368 parts of water	466 parts of water
105.8° F. - 41° C.	370 parts of water	468 parts of water
127.4° F. - 53° C.	375 parts of water	474 parts of water
161.6° F. - 72° C.	391 parts of water	485 parts of water
186.8° F. - 86° C.	417 parts of water	528 parts of water
212.0° F. -100° C.	452 parts of water	572 parts of water

Substantially lower figures were reported by Van't Hoff and Meyerhoff, and H. S. Gale in summing up their investigations stats that the solubility of gypsum gradually increases with rise of temperature from about 0.18 per cent at 32°F. (0°C.) to a maximum of about 0.21 per cent at about 104° F. (40°C). With further increase in temperature the solubility steadily decreases until at 212° F. (100° C.) it is again 0.18 per cent, or about the same as it

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was in ice water. The solubility may be increased more than three times by the addition of sodium chloride and more than four times by the addition of magnesium chloride.

According to these investigators only two forms of calcium sulphate - gypsum and natural anhydrite - are stable in the presence of any solution, and the stability of one or the other form depends on the temperature and nature of the solution with which it is in contact. In pure solution gypsum is stable only up to 66°C., when it begins to be transformed into anhydrite, but as the change takes place slowly the solubility may be determined beyond the point of its stability.

COMPRESSIVE STRENGTH

The compressive strength of raw gypsum is a matter of great practical importance, inasmuch as the load that may be assigned to gypsum pillars in a mine is directly dependent on this property. Tests of the compressive strength of several specimens have been made, the results showing strengths sufficient to sustain pressures of 2500 to 3200 pounds per square inch.

The strength of gypsum products varies considerably as a result of differences in purity, methods of manufacture, and the manner of mining.

VARIES OF GYPSUM

In its native state gypsum varies in appearance and physical characteristics, and several varieties are given specific names, as follows:

Rock gypsum.
Gypsite.
Selenite or transparent gypsum.
Satin spar.
Alabaster or snowy gypsum.
Gypsum shales.
Plumose or radiated gypsum.
Anhydrite gypsum.

Gypsum is generally white, but it also ranges in color from gray to black and is found in the light shades of brown, pink, yellow, blue and green. Pure powdered gypsum is white.

Gypsum can exist in two crystalline forms: (1) Monosymmetric (gypsum); (2) orthorhombic or labile form. When heated a period of induction first occurs, during which the monosymmetric crystals of gypsum are converted into an orthorhombic form without loss of water. [3]

Calcium sulphate also exists in combination with water as the hemihydrate, $CaSO_4\frac{1}{2}H_2O$ (orthorhombic), which sets rapidly with water. In the anhydrous form three varieties of calcium sulphate are recognized; (1) Soluble

3 - A. Brittain, Paper read at a meeting of the Nottingham Section, Brit. Chem. Soc. Feb. 21, 1923.

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anhydrite (orthorhombic) which is extremely hygroscopic and sets rapidly; (2) slow-setting anhydrite (orthohombic) which is not hygroscopic but which takes up water and sets slowly; (3) natural anhydrite (orthorhombic) which is usually regarded as nonsetting, although it has been found that this form sets slowly with water when sufficiently finely ground. When gypsum is calcined any of the above varieties can be obtained, according to the temperature of calcination.

MINING METHODS

The thickness of the overburden ordinarily determines whether a deposit of gypsum is to be mined by opencut or underground methods, or disregarded. A hard rock cover above the gypsum permits underground mining only, but where the overburden is soft, unconsolidated, and of no great thickness it is removed and the crude gypsum is mined by quarrying.

Stripping may be done either by hand or mechanically. At the smaller deposits where the overburden is shallow the material is shoveled by hand into carts or into a worked-out pit. Where the overburden is exceedinly thick and the deposit covers a large amount of ground steam shovels are more economical. The shovel generally loads directly into cars, which may be used afterward for removing the crude gypsum to the mill. Horse scrapers are sometimes used, the overburden first being loosened by plow. Scrapers are likewise employed to a considerable extent in some of the Western States for mining gypsite or earthly gypsum. Steam shovels could be used in digging gypsite, but as the deposits are generally small and of no great thickness the horse scrapers are usually more economical. At some places gypsite is dried after breaking it up with a disk harrow and is stored under sheds for use in wet weather because it can be pulverized and worked more easily when dry.

For rock gypsum open quarrying has many advantages and is the method used wherever possible. The advantages over underground mining include cheaper operating costs, easier handling and supervision, easier selection of material, complete recovery, and in some places better working conditions. In only a few places, however, has quarrying practice results in systematic exploitation. The openings for the most part are irregular, having been carried back from the outcrop to the limit of economical stripping or of safe working and along the outcrop for a greater or less distance.. Often, an open quarry, after it has been extended to the maximum limit consistent with safety or economy, is abandoned and a new opening made a short distance farther along the outcrop. On the other hand, where the thickness of the overburden is moderate, single quarries may be of large size.

Rock gypsum is broken from the ledge by blasting with low-power explosives. If the face is high enough it is broken down by caving. Holes are drilled in the lower part of the ledge with an auger or hand-power drill and blasted with light charges. Black powder is used where there is no moisture, but as a rule low-grade dynamite (18 to 20 per cent) is used for blasting and for breaking the large chunks. The blocks of gypsum thus brought down and broken with explosives or with wedges and sledge hammers to a size convenient for handling are loaded into wagons or cars for hauling to the mill or loading

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platform. In hand loading there is opportunity to sort out inferior material.

In inclined beds or places where the overburden becomes too thick to be cheaply removed mining may be continued beyond the quarry face by underground methods. This requires that a large part of the gypsum bed be left as pillars to support the roof. After a number of years of work, as the underground passages become very extensive, it may be cheaper to sink a new shaft than to extend the long haul to the outcrop.

The underground methods used for mining gypsum are similar to the room-and-pillar system used in coal mines. Main haulageways are driven and rooms laid off from them, pillars being left between the rooms to support the roof. The room-and-pillar system is the simplest and usually the most practical method of underground recovery of a flat-lying bed, although it may entail the loss of a considerable part of the deposit. The pillars usually are composed of good gypsum and constitute about 25 per cent of the bed. Where gypsum is not left as a roof and where pillars can be drawn and the surface allowed to cave a bed may be completely mined out, but rarely more than three-quarters of a deposit can be extracted by underground mining. As in open quarries, the gypsum is drilled by hand or power augers or drills. Tracks are laid to the working faces; and the broken gypsum is loaded directly into cars, which are trammed by hand or by mule to the main haulageway, where they are made up into trains and hauled to the surface or to the foot of a shaft by mule, by cable, or by electric locomotive.

PREPARATION OF PRODUCT

When different parts of the bed vary in composition the purer rock may be sent to the mill for plaster, and the impure gypsum separated by hand sorting may be utilized for land plaster. Preparing gypsum for land plaster consists only of crushing, drying, and grinding. For making other gypsum products the rock goes through these operations: Crushing, drying, grinding, calcining, screening, regrinding and mixing. The order in which these operations are performed differs in practice.

Crushing

Rock gypsum is delivered to the mill in blocks no larger than one man can handle, or as in the case of rock imported from Canada and Mexico, in sizes ranging from fines to a product which passes a 6-inch ring, and is dumped into a bin or chute or on a platform from which it is fed directly into a large jaw crusher or a rotary crusher. The rock is broken to somewhat less than the size of a man's fist or about 2 inches.

Where the quantity of rock handled is large and the lumps vary considerably in size, economy in power is gained by running the crude rock dumped from the mine car over a grizzly, or set of parallel iron bars to sort out the material smaller than 3 inches and by feeding the undersize directly to the secondard crushers.

From the first or primary crusher the broken rock slides directly into the hopper of a secondary crusher installed below. Other forms of crushers

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for gypsum are apparently being superseded by hammer mills. According to one operator, these mills give a very satisfactory feed material for Raymond mills and have corrected somewhat the troubles at the mills due to tramp iron. Tramp iron or steel mixed accidently with the gypsum in mining is usually removed by a magnet, which may be placed either on the plate over which the broken rock slides from the primary crusher to the secondary crusher, or suspended over a belt conveyor carrying the crushed rock from the secondary crusher. In the latter position the magnet does not protect the crusher, but it makes more certain the removal of the metal. Sometimes a magnetic pulley is used at the end of the conveyor from the crusher which attracts and throws out all metal before it reaches the secondary crusher.

Drying

In most plants, especially in this country, the rock goes through a dryer after crushing. The dryer is a large, slightly inclined, rotating cylinder. Crushed rock is fed into the upper end and hot gases are forced into the lower end. The surface moisture taken from the rock as it passes through is carried off by an exhaust fan. The dry rock discharged has a temperature of about 150° F. and is elevated to a storage bin at the top of the crusher building. To avoid staining the rock with smoke a mixture of coke and coal is used commonly for heating the dryer.

Grinding

From a bin at the top of the building the crushed rock is fed by gravity through chutes to the pulverizers. The type of pulverizer used is not uniform, there being four that are giving service - burr mills, emery mills, disintegrators, and roller mills.

Burr mills.--A burrstone mill consists of two rough, siliceous stone disks; one of these is stationary and the other revolves concentrically against it. The stones are set either horizontal or vertical. Radiating grooves are cut into the grinding surface of each stone and must be recut when the surfaces are worn smooth, which is about once a fortnight. Extra stones are kept on hand that time may not be lost during redressing. The vertical mills grind faster but not as uniformly fine as the horizontal mills. Burr mills reduce the partly crushed rock to 60 mesh or a size that will pass through a screen having 60 holes to the linear inch. The capacity of the mills varies but will average 30 tons of 60 mesh in 24 hours. The mills are driven at speeds ranging up to 650 revolutions per minute. After the first grinding the material may be screened and reground so that 85 per cent will pass a 100-mesh screen.

Emery mills.-- Built on the same plan, but with different material for grinders, emery mills are an improvement on buhrstone mills. The grinders have a center of buhrstone surrounded by concentric rings of grooved emery blocks. The whole is surrounded by an iron band and the loose blocks outside the buhrstone core are case in metal. This type of stone was devised to remedy the wearing away of the outer part of the buhrstone more rapidly than the center.

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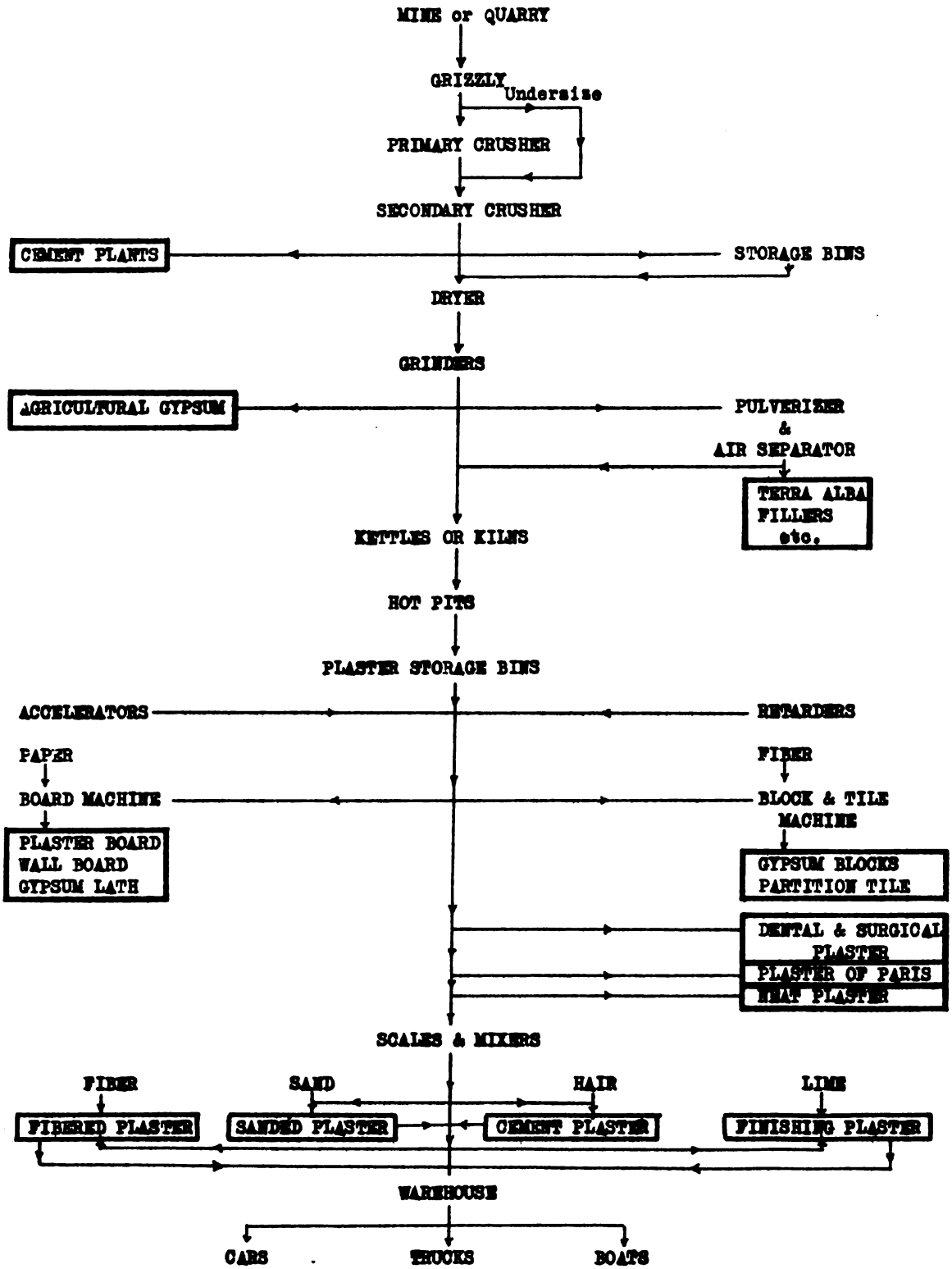

FIGURE 1. TYPICAL GYPSUM-MILL FLOW SHEET

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Disintegrators.-- A machine especially adapted to pulverizing soft rock, such as gypsum, has come into extensive use in gypsum mills. It consists of two circular plates revolving concentrically in opposite directions on a horizontal axis. Each plate is armed with a double circle of short iron bars attached at right angles and so placed that they interlock with those of the other plate, thus forming a circular cage made of four concentric rows of posts. The crushed gypsum fed into the center of the cage drops against the first set of iron bars. The impact with these bars breaks the gypsum, and it passes between them to be struck at once by the second set of bars moving in the opposite direction. By the time the outer set of bars is passed, the rock is reduced to a powder. Speed regulates the fineness.

Roller mills.-- A method of producing a fine uniform product by grinding and air separation used in a number of gypsum plants is known as the Raymond system. Grinding is done by suspended rollers, and all working parts are inclosed in a tight metal case. At the top of the main shaft, which is vertical, is a rigidly attached spider that rotates with the shaft. To the spider arms the roller journals are pivotally suspended by trunnions fastened in the top and carried in bearings in the spider. The speed of the machine regulates the pressure the cast iron rollers exert on the grinding surface, which is a full ring made of high carbon steel. A steel plow ahead of each roller throws a stream of material between the face of the roller and the bull ring. A fan driven by an electric motor makes an air current that carries away pulverized material. Selective separation of the ground rock is regulated by the speed of the fan. The air current also delivers the pulverized material to the bins above the calciners, whereas from other types of pulverizers the pulverized gypsum is raised by elevators, usually the bucket-belt conveyor type, to storage bins.

PRIMARY PRODUCTS

Cement Retarder

The manufacture of calcined gypsum plasters consumes by far the largest part of the domestic output. A considerable quantity, however, is sold and consumed in the cement industry without further preparation. Raw gypsum crushed to pass through a half-inch screen is added to the cement clinker and ground with it. It is generally added in the proportion of 3 per cent of gypsum to the total quantity of cement. At some gypsum plants the rock as it comes from the quarry or mine is passed over a screen having one-half to three-quarter inch openings. The rock passing through is stored in the bin below and shipped to the cement plants, while the larger sizes are carried into the plant for further crushing. In this manner gypsum for the cement industry does not go through any crushing operation, and therefore, there is very little addition to the cost of the crude ore to the cement plants.

Some cement plants prefer calcined gypsum, even though the cost per ton may be more than twice that of the crude ore. For this purpose the calcined gypsum is finely ground and added to the finished cement in very carefully measured quantities and is thoroughly mixed to insure a uniform set.

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Sulphur trioxide (SO_3) is the active agent in the gypsum which renders it valuable as a cement retarder. Cement should not develop its initial set in less than 45 minutes, not its final set in less than ten hours.[4]

According to generally accepted conclusions, high-alumina cements require more sulphur trioxide to make them usable during the hot humid season than do the low-alumina and high-iron oxide cements. The finer a cement is ground the more sulphur trioxide is required to prevent it from setting too quickly.

Anhydrous gypsum (anhydrite) contains a higher percentage of SO_3 than is found in gypsum proper. Some chemists at cement plants have no objection to the use of anhydrite as a cement retarder, while others actually prefer it, as 1 ton of anhydrite contains more SO_3 than 1 ton of gypsum, and the cost is somewhat lower. The sulphur trioxide content of the gypsum used in Portland cement must be fairly constant or an uneven set in the cement results. It seems probable that where trouble has resulted from the use of anhydrite the cause is often to be found in the fact that the percentage of SO_3 was not uniform, rather than to the nature of the anhydrite itself. Anhydrite almost invariably occurs mixed with gypsum, and if it is used some care must be taken to see that the gypsum and anhydrite are so mixed by mechanical processes that the SO_3 content is uniform throughout the entire mass.

Agricultural Gypsum

The second largest use of raw gypsum and one of the earliest uses in this country is as land plaster or fertilizer. It has a very beneficial effect with some crops, especially clover and other leguminous plants.

The history of the use of gypsum as a fertilizer dates back a little more than 150 years. The earliest use of gypsum for this purpose probably occurred in Wurttemburg, in southern Germany. Memoirs of the Economic Society of Berne, in 1768, contain the first account of the use of gypsum on the farm. In the United States the use of gypsum as a fertilizer was mentioned as early as 1796 in Virginia.

The action of gypsum as a fertilizer is indirect, and it does not act as a plant food itself. It is supposed to act on the double silicate of magnesia and potash, setting these substances free to act as a plant food.

Land in the Western States which contains black alkali, or which upon being irrigated develops it in excess, to the detriment of crops, is made usable by the application of gypsum. The carbonates of soda, potash, and magnesia, which form black alkali, are changed to sulphates, which are less injurious to plants.

Nitrogen, one of the most important and certainly one of the most expensive forms of plant food to purchase in chemical form, is effectively and cheaply supplied to the soil indirectly by the use of gypsum. The legumes

4 - A. S. T. M. standards, 1918, p. 504.

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contain numerous nitrogen-secreting bacteria and respond tremendously to a sulphur fertilizer like gypsum. Moreover the gypsum has a very stimulating effect on the nitrogen-gathering or nodule-forming bacteria of red clover roots.

Potash is abundant in most soils, and normally enough of it is present in an insoluble condition even in the first 6 inches of surface soil to meet the needs of hundreds of years. By the reaction of gypsum on the potash silicates soluble potash is liberated without waste in sufficient quantities to feed the crops. This action is assisted by turning under a green crop occasionally.

Except for garden plots and truck farms where the large returns per acre justify expensive mixed fertilizers, it is in the interest of economy and efficiency to supply nitrogen by means of legumes and to add natural rock fertilizers - notably gypsum and rock phosphates - suitably ground. Lime is essential also to keep the soil in an alkaline condition, which makes it congenial to most crops.

The sulphur essential to the legumes is best and most cheaply furnished by gypsum. Raw sulphur is effective, though it rapidly sours the soil and this tendency must be constantly checked by the addition of lime. The sulphur must be transformed into lime sulphate by chemical reaction in the soil, whereas gypsum, a neutral salt, is itself a lime sulphate.

Experiments by the United States Department of Agriculture show that gypsum has given remarkable increase in the yield of cotton.[5]

The results are shown in the table below:

Kind of fertilizer used	Total fertilizers per acre used			Average crop increase per acre 1/		net Average gain per acre
		Pounds	Dollars	Pounds	Dollars	Dollars
Nitrate of soda	73	160	4.00	64.0	6.40	2.40
Sulphate of ammonia	17	128	3.97	58.2	5.82	1.85
Acid phosphate	181	286	1.90	69.8	6.98	5.08
Ground bone	14	279	3.63	92.8	9.28	5.65
Rock phosphate	6	706	3.18	4.0	.40	3.58
Floats	25	201	.80	16.7	1.67	.80
Basic slag	4	230	1.42	1.0	.10	1.52
Bone black	3	500	5.50	132.7	13.27	7.77
Muriate of potash	36	98	2.16	34.5	3.45	1.29
Sulphate of potash	6	112	3.36	21.2	2.12	1.24
Kainit	161	292	1.75	32.3	3.23	1.48
Wood ashes	3	1,667	4.17	68.0	6.80	2.63
Cottonseed hull ashes	12	271	4.61	41.6	4.16	.45
Lime	3	1,333	4.00	33.3	3.33	.67
Marl	3	900	.23	19.0	1.90	1.67
Salt	1	200	.80	8.0	.08	.88
GYPSUM	11	195	.78	197.4	19.74	18.96
Total	559		2.33	54.0	5.40	3.07

1/ Value of cotton, 10 cents per pound.

5 - U. S. Dept. Agriculture, Bureau of Soils, Bull. 62.

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Other Uses

Very white gypsum, which has been ground and bolted through a 200-mesh screen, is sold as a filler for paper and paint under the name of Terra Alba. In the making of paper, its function is to close the pores and permit a hard glossy finish. The blueing and match industries also use large quantities as fillers. The readiness with which it can be ground to pass 200 mesh is an important property that makes gypsum an admirable filler in these industires.

In certain processes gypsum is added as a flux to galena concentrates. In Germany it is used similarly in the smelting of lead-copper matte in reverberatory furnaces. Large quantities are required in the smelting of certain nickel ores in New Caledonia; the gypsum in this case furnishes the sulphur necessary for collecting the metal into a matte and also acts as a base to counteract and slag the siliceous gangue. It has been used as an adulterant in flour, sugar, baking powder, etc. Mixed with a pure grade of wheat flour it makes what is known as Corine flour, used to dust molds for metal castings in foundries.

Finely-ground raw gypsum as well as calcined gypsum is used to dilute arsenic poisons that are employed in combating insets. Hundreds of tons of gypsum are used annually for this purpose, especially in the cotton-growing States of the South. Large quantities are also used in fighting potato bugs. The following experiment was one of a series tried by the Department of Agriculture in its endeavor to find suitable methods to control the pest.

> Experiment No. 6. - This plot was treated with a mixture of Paris green and land plaster at the rate of 1 pound of Paris green to 50 pounds of plaster, the mixture being put into a coarse burlap bag and sifted over the plants by a negro laborer in the usual plantation manner, the amount of dust used being at the rate of 320 pounds per acre. The wind prevailing at the time carried a large part of the dust from the plant as it was applied, but the portion remaining was sufficient to thoroughly destroy the larvae by 48 hours afterwards. This mixture killed 90 per cent of the larvae during the first 24 hours, and is very effective in controlling the potato bug.

The mineralogical term "alabaster" is applied to pure white, semi-transparent gypsum which is used for statuary and vases. Its softness renders it easier to work than marble but the same property renders it less durable.

The common school crayon known as chalk is made from finely ground uncalcined gypsum. The gypsum, with a suitable binder, is molded under pressure.

Numerous patents have been issued to cover processes of hardening gypsum blocks till they equal marble. Some ambitious attempts have been made to establish a gypsum industry along this line. The processes are often successful, but until only recently none have been able to survive under actual

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business conditions. The United States Gypsum Co. has recently announced its intention of placing on the market a load-bearing tile called "structolite."

Numerous patents have been issued for extracting sulphuric acid from gypsum, and during the war it is stated that Germany depended largely on gypsum for her supply of this essential. When calcium sulphate is treated in an open tube it decomposes at 1200° C., the products being CaO and SO_3. When it is mixed with molecular proportions of silica the temperature of dissociation is 1005°.

Gypsum may be converted into Na_2SO_4 (sodium sulphate) and the latter into $HaHSO_4$ from which the free H_2SO_4 may be obtained.

Raw gypsum is used in the manufacture of rubber goods and phonograph records. With other substances it enters largely into the composition of certain kinds of buttons. It plays a useful part in the filtering and refining of oils. It is sometimes added to water used for brewing.

Permanent hardness is desirable in water used in brewing, and the property is chiefly due to calcium sulphate. In some sections of the country where the water is not of this character, it is customary to add gypsum. In such cases the gypsum must be free from marl.

The following table gives an average analysis of brewer's gypsum:

Analysis of Brewer's gypsum

	Per cent
Gypsum	98.84
Silica	.34
Alumina and ferric oxide	.34
Magnesia	.08
Alkalies	.14
Uncombined moisture and organic matter	.26
	100.00

Both in this country and in England there is some demand for the lowest grade of gypsum for polishing tin plate. The material used may be described as marl full of gypsum veins, ground to fine powder. The darker kinds are preferred by some firms on the ground that they are less dusty.

CALCINING

Calcining is the process of partly or completely dehydrating gypsum by heat. Two district groups of calcined gypsum products are recognized in the arts. The first and more important group consists of gypsum that has been calcined at temperatures not exceeding 400° F. The second group includes gypsum products resulting from calcination at high temperatures, that is, from 1652° to 2552° F. (900° to 1400° C.)

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In the early beginning of the industry on this continent gypsum was "cooked" in caldrons and stirred by hand. These caldrons had a capacity of only a few barrels and were heated with wood fires. The massive gypsum was broken with sledges to small size and may have been ground before calcining. At one place in Utah in recent years ranchers have made gypsum plaster by burning the rock in a rough stone kiln over a wood fire. It is assumed that the rock was cooked in lumps and crushed or ground in a portable mill after calcination.

Most of the plaster of Paris and wall plaster made in this country is calcined in specially constructed vertical cylinders called in the trade "kettles." Continuous rotary calciners are used in some of the American plants, and to some extent in other countries, notably Germany.

Most American gypsum mills calcine in kettles holding 8, 10, 12, or 15 tons, those of 10-ton capacity being most common. The kettle consists of a steel shell cylindrical in shape, 8, or 10 feet high and with the bottom arching up from 6 to 12 inches. It is made of steel from three-eighths to three-quarters inch thick, and the bottom may be either cast iron or steel and 1 to 3 inches thick. In some instances sectional bottoms of six or more pieces are used.

Four flues are commonly present in each kettle; they may be placed about 18 inches from the bottom, or one pair may be so placed and the other pair 12 or 14 inches above them. The kettle shell is inclosed with fire brick, leaving a space of 6 to 14 inches between the brick and the shell itself. The kettle rests upon a heavy cast lip ring. This ring is carefully protected from direct exposure to the heat of the fire box by fire brick. There is a space of 4 to 7 feet between the grates and the fire box, and the whole design of the kettle is intended to distribute the heat on the sides and through the flues of the kettle so that the bottom shall not be exposed to excessive temperatures.

The vital point in a calcining kettle is the bottom. The greatest trouble in connection with the operation of calcining kettles comes from leakage through the bottom, or at the contact of the shell and the bottom with the lip ring. Hot gypsum, ground so that 90 per cent passes a 100-mesh screen, flows almost like water and will escape through very minute cracks. Steel bottoms do not crack as readily as cast iron, but they may buckle badly and pull away from the sides and allow the escape of uncalcined gypsum.

Should any uncalcined gypsum escape into the hot box and become mixed with the calcined material a product of uneven set will result. Great care therefore must be taken that none of the uncalcined material escapes into the hot box.

The chemical changes that take place in the kettle correspond to definite temperatures and are accompanied by certain characteristic manifestations. When the temperature reaches 262° F. (128° C.), steam begins to come off very rapidly, due to the breaking up of the molecules of water of crystallization. The self-recording thermometers commonly used on modern kettles

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may not register quite this temperature when the "first boil" - as this stage is called - begins, but the material nearest the heated surfaces has, in places at least, reached this temperature. The temperature of the kettle, which hitherto has been rising rapidly, remains almost stationary while the mass within the kettle "boils" violently. The length of time that the boiling at this stage continues depends upon the size of the kettle and the vigor with which it is fired, but in the average practice it ends in about 45 minutes. The temperature begins to rise rapidly again and the plaster in the kettle becomes relatively quiet, that is, "enters the first settle."

It is the generally accepted opinion that wall plaster made from material drawn from the kettles during the first settle works more easily and is more plastic than that made from material that has been further calcined. For wall plaster, therefore, the contents of the kettle are generally discharged when the temperature is between 330 and 340° F.

Gypsite takes very much longer to calcine than ground rock gypsum. This is due to the higher water content of gypsite. If the gypsite has not first been passed through a dryer, from six to eight hours may be needed to calcine a single kettle charge, consequently kettles with large capacities are commonly used in gypsite mills.

After the calcined gypsum is emptied into the hot pit, it is carried to bins above the mixing and packing machines by spiral conveyors and belts. These bins aerate and cool the hot material. As the plaster is needed, it goes into the mixers where the amount of retarder is added together with hair, wood or sisal fiber and hydrated lime or clay according to the type of plaster required. Here the ingredients are thoroughly mixed, and the plaster is carried to the bagging machine, which in practically all plants now are automatic.

In an apparatus developed by Hermann Voelker of Munich, raw gypsum is calcined by coming in contact with a coil filled with oil heated to a proper temperature.[6]

MANUFACTURED PRODUCTS

The most important use for calcined gypsum, amounting to about 2½ to 3 million tons annually, is as wall plaster, often called stucco. The whiter varieties are called, in connection with certain trades, plaster of Paris. Wall plaster, commonly known as hard wall plaster, may be grouped into four classes: (1) Cement plaster - which contains calcined gypsum and retarder, with or without hair; (2) wood-fiber plaster, which contains calcined gypsum, retarder and wood fiber; (3) prepared plaster, which contains calcined gypsum, retarder, sand, and hair or wood fiber; and (4) finishing plaster, which contains calcined gypsum, with or without retarder, and with or without hydrated lime.

Types of Plaster

Neat gypsum plaster. - Neat gypsum plaster (more commonly but wrongly called "cement plaster") ordinarily contains no less than 85 per cent of cal-

6 Chem. Abstracts. Vol. 23, No. 12. June 20, 1929. p. 3057.

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cined gypsum, the remainder being hydrated lime, ground clay, asbestos, retarder, or fiber. Four to six pounds of goat or cattle hair are used in each ton of plaster. In addition some manufacturers use one or two pounds of manila or sisal fiber. The purpose of the fiber is to hold the plaster together while it is being applied and to prevent it from dripping from the keys that are formed behind the lath.

Wood-fiber plaster. - Wood-fiber plaster contains at least 80 per cent by weight of calcined gypsum and not less than 1 per cent of a nonstaining wood. The remainder may be composed of hydrated lime, ground clay, asbestos, sand or substance of similar nature, and retarder. Thirty to forty pounds of shredded poplar, lime, willow, or buckeye wood are used to a ton of plaster.

Wood-fiber plasters are intended for use where sand is scarce or expensive, or where unusual toughness and a measure of flexibility is desired. They are intended to be used without admixture of sand and are especially convenient for patch work. Most sand has an accelerating influence on gypsum plasters, since they are prepared for use without sand; less retarder may be used than for those kinds intended for use with sand. Ordinarily 4 or 5 pounds of commercial retarder to the ton will keep such plaster in proper working condition for two hours, which gives ample time for mixing and applying.

Considerable quantities of ready-mixed gypsum plasters are shipped from some mills. In some of the larger cities, mixing plants take the calcined gypsum in car lots and mix it with sand for the local trade. It is not economical to ship sanded plasters any considerable distance. If local sands are not suitable for mixing, it is generally cheaper to use wood-fiber plasters.

Keene's cement. - Keene's cement consists of dead-burned gypsum, that is, gypsum heated to 500 to 600° C. (900 to 1100° F.) to which the property of quick setting is restored by the use of certain salts which act as positive catalysers. It is made by calcining lump gypsum to a red heat; treating with a 10 per cent solution of alum; reburning to a dull red heat and then grinding. The solution commonly used in making Keene's cement (which is also known as marble cement, MacLean's cement, alum cement, and in France as Cement Anglais) consists of 77 to 83 grams of potash alum to a liter of water. Hot water is generally used, thereby increasing the solubility of the alum.

Keene's cement as originally made in England was produced by burning lump gypsum at a temperature only high enough to produce the hemihydrate ($2CaSO_4, H_2O$), soaking the lumps in a solution of alum, or aluminum sulphate and recalcining at 500° C. (932° F.), after which the lumps were ground.[7] Instead of lumps, finely-ground calcined gypsum may be used. In this case the calcined gypsum is mixed with the alum solution and the hardened masses are broken up and burned in a vertical or a rotary kiln at temperatures of 900 to 1400° F.

It is reported that most of the producers of so-called Keene's cement in this country calcine lump gypsum in stationary kilns, grind it to a very fine powder, and add a small amount of powdered borax and other chemicals. The mixture is not recalcined and is marketed as American Keene's cement. Mixtures of aluminum sulphate and sodium sulphate are doubtless employed to to give the burned gypsum proper setting properties.

7 Encyclopedia Brittanica, 11th Ed., Vol. v, p. 658.

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The amount of standard retarder used in different kinds of gypsum plasters may vary from one to fifteen pounds per ton of plaster. Gypsite plasters, as previously noted, require very little retarder other than the clay naturally present. Wood fiber plasters for use without sand require only 3 or 4 pounds of retarder, while plasters intended to be mixed with three parts of sharp sand for use on brick or terra cotta may require 8 or 10 pounds of retarder.

Plasters intended for mixing by machine are retarded heavier than other plasters, for it is difficult to keep the mixer clean, and additional retarder is needed to overcome the accelerating effect of set plaster.

Plate Glass

Many thousands of tons of calcined gypsum are used annually in connection with the plate-glass industry. The glass is imbedded in gypsum paste preparatory to polishing and is held by a gypsum matrix during the polishing process. The strength required for this purpose is not great, and the set gypsum may be crushed, ground, and recalcined. Some fresh mineral is added each time, however, to give greater life to the plaster. For plate-glass purposes material free from grit is required, and this is secured by using gypsum of great purity or by exceedingly fine grinding.

Surgical and Dental Casts

Plaster casts are commonly used for holding broken limbs in place while the bone is knitting. During the war hundreds of tons of domestic plaster of Paris were used in making orthopedic bandages. Open-mesh bandages are passed through a tray containing plaster till the meshes of the fiber are filled. They are then rolled while dry and laid away for use. When applied, the rolls are soaked in water 10 minutes and then unrolled and wound firmly about the injured limb until a closely-knit strong splint is produced.

An exceedingly fine fast-setting plaster is used in making dental molds.

Plaster of Paris, finely ground and properly colored, is sold in small and large packages for tinting interior walls and ceilings. It is said that 40 tints can be made from three colors, red, white, and blue, by mixing with white plaster. Five pounds of the plaster will cover 50 square yards of surface.

Considerable quantities of calcined gypsum are required for pottery and terra cotta molds. Gypsum for this purpose is usually calcined to the second settle; it is short working and dense. Up to 1916, most of the pottery plants insisted on having material made from Nova Scotia gypsum, but when this supply was cut off by the war it was found that some beds of domestic gypsum gave equally good results.

In the manufacture of confectionery, a very find grade of calcined gypsum is used as molds, especially in chocolate covered bonbons.

Plaster and Wall Board

The methods used in manufacturing gypsum plaster board and wall board are quite similar. Since wall board gives a finished surface, while plaster

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board is covered with plaster, it is essential that wall board be uniform in thickness and attractive in color. These properties are not so essential in plaster board. It is necessary to have thickness sufficient for strength, but the fact that some plaster boards are somewhat thicker than others does no harm.

A satisfactory bond between paper and gypsum matrix is highly essential in both types of boards. Considerable care must be taken in the mixing of the paste, for the intergrowth of the crystals into the chip board seems to take place most efficiently during the earliest stages, and "peelers" may result if mechanical mixing is used. Crystallization, which is accelerated by agitation, must not go too far in the hopper, or the board will lack strength. The chip board must not be sized enough to prevent moderately prompt water penetration, as the water carries with it some gypsum which becomes crystallized in the fiber and thus binds together firmly the matrix and the chip board. On the other hand, if the chip board takes up water too quickly it loses its stability and tends to wrinkle.

The chip board is delivered in large rolls; and the gypsum paste, made by mixing slightly accelerated calcined gypsum and water, either on the lower sheet or in a mixer, is spread out between the layers of paper as the plastic mass passes between rollers. The edges are either molded, trimmed with saws, or made true by folding the edge of the lower sheet of the chip board under or over the edge of the upper sheet. If the lower sheet is folded over the upper the flap is turned over about 1 inch and is run through two abrasive wheels so as to taper the edge of the paper.

The plaster board is allowed to run out on a traveling belt until the plaster has set sufficiently to make it possible to handle the boards without breaking. It is then either cut into appropriate lengths by knives or saws, or perforated so that the sheet can be broken to size.

After the plaster in the board has hardened so that the board may be handled conveniently, the boards are placed in a dryer and subjected to moderate heat to remove the surplus water in the chip board. The temperature must not reach a point which would derive the gypsum of any of its water of crystallization.

Steam radiators are commonly used to furnish the heat, although in some instances carefully regulated direct heat obtained by burning coke in a furnace attached to the dryer is used.

Gypsum Lath

Other new products similar to plaster board are now on the market. Rock lath has a fireproof plaster base and is made in sizes ranging from 18 by 32 inches to 48 by 32 inches, and is 3/8 inch thick. The laths are packed in bundles of six or eight, according to size.

Lock lath is a plaster lath or board, and although constructed of gypsum plaster and paper it bears little resemblance to what the trade knows as ordinary plaster board. The chip board used is saturated on one side with liquid asphalt, thus overcoming the penetration of moisture into the plaster

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core, which brings about lack of strength in the board. Then again, the failure of the bond between the lath and plastering material when subjected to high temperatures such as would be experienced in case of fire, due to the burning of the chip board of the ordinary plaster lath, is overcome by the grooved face which is characteristic of lock lath. This grooved face forms a perfect bond between the plaster and the lath even after the paper has been charred. The only size in which these laths are made is 48 by 16 inches.

Block and Tile

The manufacture of gypsum block and tile in the United States started about the year 1900, and by 1904 the American gypsum-block industry was on a firm footing.

Gypsum blocks consist of not less than 95 per cent gypsum by weight and 5 per cent or less of nonstaining wood fiber. First settle calcined gypsum is used ordinarily in their manufacture.

Gypsum blocks as used in nonbearing partitions are best known to the building trade. Closely related to the partition block is the furring block, which is merely a partition block split or sawed through the center.

Blocks, generally reinforced, are used in roof construction. They may be made at the factory or poured on the job. The compressive strength of gypsum is of considerably more importance for use in floor and roof construction than for any other purpose. The compressive strength of gypsum depends upon the amount of water used in mixing, the method of calcining, the dryness of the material, and the purity of the mineral. First-settle gypsum has been used successfully for roofs and floors, though its compressive strength is not equal to the second settle product.

Gypsum carrying impurities sufficient to affect its compressive strength may be used for flooring and roofing provided the cross section of the slab is figured somewhat more liberally to allow for any difference in strength. For any rock gypsum now in commercial use the increase in the section required to balance such impurity would be small.

As gypsum is an exceedingly poor conductor of heat, it has an important advantage over certain other substances used in making roofs and floors. A gypsum roof slab as ordinarily made shows a heat loss per square foot per hour, for each degree difference in temperature, of 0.4 B.t.u. as compared with 1.2 B.t.u. loss for an equal thickness of cinder concrete, and 2.0 B.t.u. loss for an equal thickness of stone concrete. These figures justify the statement that where a gypsum roof is used instead of cinder concrete, between latitudes of 39 and 42, there is a saving of 10 per cent of the initial cost of the heating plant, and a saving of 20 to 25 per cent in the cost of fuel. These savings are, of course, greater if comparison is made with stone concrete, and are still greater as compared with clay tile.

These figures showing relative nonconductivity are as favorable to gypsum if summer conditions, instead of winter conditions, are under consideration. The gypsum roof is cool, and lofts may be used with comfort where gypsum is the roofing material, which would be intolerable otherwise.

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An important fact that deserves special mention is found in the protection given by gypsum roofs and floors to the structural steel that carries the weight of the building. At temperatures of only 800° F. steel loses 10 per cent of its strength, and at 1700° F. it loses 50 per cent of its strength. It is exceedingly important, therefore, that in fireproof buildings, where the contents of the building may create high temperatures, that the steel be given ample protection.

Gypsum roofs and floors are lighter than any other form of fireproof construction. Certain types of poured roofs do not weigh over 12 pounds per square foot for average purlin spacing, ready for finish or waterproof surfacing. A 4-inch poured slab weighs but 16 pounds per square foot. Precast roof blocks have the following weights:

Type	Length (inches)	Thickness (inches)	Width (inches)	Weight per sq. foot, lbs.
Solid	30	3	12	13
Hollow	30	4	12	14
Slabs	48 to 72	5	15	14 to 16

The 30-inch blocks, either solid or hollow, set in Tee-iron sub-purlins, save 40 per cent in steel over clay-block tile construction.

Gypsum roofs and floors are more elastic than concrete structures and the vibrations from machinery or other causes do not develop cracks, which are often troublesome where a less resilient construction material is used.

The rapidity with which gypsum sets makes rapid construction possible. The forms or centers from poured units can be removed in 20 to 30 minutes. In the case of a poured roof or floor the resulting surface is sufficiently strong to be used at once, and, within an hour, provides a working floor that may be safely used under the loads for which it was designed. The use of precast gypsum roof blocks, on account of the large size of the unit and its lightness, promotes rapid construction.

In the case of poured roofs and floors, the gypsum generates considerable heat while setting and it is possible to proceed with the work even when temperatures are considerably below freezing.

The steel reinforcement used in structural gypsum is remarkably free from corrosion. Wires which have been imbedded for 15 years have been examined repeatedly and, aside from a thin film of initial rust that always forms when a wet substance touches metal, the steel is as bright as when installed.

Gypsum has been used as a roofing material in America since 1898; and sufficient time has elapsed, therefore, to demonstrate its durability. Gypsum roofs are of two types, the poured roof, and the roof slab. Each type has its advocates but ordinarily local conditions will determine which should be employed. Both systems adequately meet all requirements for fire protection, durability and economy.

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The principle involved in the poured roof is that of the suspension bridge. Steel cables, properly spaced, carry the entire load with an ample margin for safety, to which factor of safety may be added the compressive strength of the gypsum roof deck. Cables composed of galvanized wires are carried over the tops of the beams on purlins and are secured to them and the walls by strong hooks, bars or anchors. The cables are laid parallel to each other at intervals of 1 to 3 inches, varying according to spans and loads. The cables pass under an iron bar midway between the purlins which causes a uniform deflection in the cables. Forms are placed about an inch below the round iron bar which crosses the center of the cables. When the gypsum paste is poured on this form till it stands about one-half inch above the tops of the purlins, the slab has a thickness of about three inches.

The gypsum paste consists of calcined gypsum and water, with planer shavings or shredded wood, preferably of some nonstaining sort. The percentage of water used in mixing is highly important as it affects the compressive strength of the slab more than any other single factor. Over the gypsum slab a layer of ordinary slag roofing is commonly poured. A variety of waterproof compounds may be substituted for the slag cement, any one of which will successfully keep water from the gypsum slab, which is so essential.

Factory-made blocks, reinforced, but otherwise like gypsum partition blocks, are used in roof construction. The tendency, however, is to use larger units, molded on the job, such as blocks 10 feet long, which extend from truss to truss and eliminate the Tee-irons ordinarily used in roof construction.

The same types of construction used for roofs are appropriate for floors in fireproof buildings. In addition to these a gypsum floor tile or filler for use in reinforced concrete floor construction is popular. These floor tile or domes are light and permit of long floor spaces. They have solid ends which reduce the loss of concrete at the points where cement is poured. The bottom of these tiles makes an excellent surface for the plaster of the ceiling formed by the floor.

Floor tile of this type are spaced 24 inches on centers and are about one-half the weight of clay tile.

Partition Tile

Gypsum partition tile are either solid or partly hollow, depending on their thickness and on the load they are intended to carry. The 2½ and 5 inch sizes have single rows of core holes. The 6 and 8 inch sizes have two rows of core holes.

The tiles are either hand molded or machine made. The hand-molded tile is equal in quality to the machine-made article. Economies growing out of the application of elaborate machinery to the manufacture of gypsum tiles have not been very great, and in consequence the machinery used is relatively simple.

Hand-made tiles are molded on rubber mats. A frame with height equal to the thickness of the block desired is used to hold the plaster mixture.

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Calcined plaster which has been mixed with fiber and water until it has the consistency of thick soup is poured into the frame, which is so constructed that it can easily be detached from the contents of the frame as soon as the plaster has set. The calcined plaster is not retarded and the hardened block can be removed from the frame a few moments after pouring.

Wooden cores, tapered so that they may more easily be removed after the block hardens, are inserted in the frame before the calcined gypsum paste is poured. When hollow tiles are machine made, various mechanical appliances are used to force out these cores after the tile has hardened. Hand-made tiles often have a greater crushing strength than machine-made, due to the fact that hand mixing is not carried on as long as machine mixing, nor is the paste agitated as much.

SUMMARY OF ADVANTAGES OF GYPSUM BUILDING MATERIALS

Gypsum block and tile are 30 to 36 per cent lighter per square foot than any other structural material of a similar nature and of equal thickness. This greatly reduces the load on columns, girders, and all supporting members and permits the use of steel with smaller cross section.

Heat Insulation

Gypsum is a poor conductor of heat. This important property adds to its value in every one of the many forms in which it is used as a building material. While its low heat conductivity is a valuable asset of gypsum plasters it is an even more important property of gypsum block and tile.

Compared with other commonly used fireproof materials a gypsum roof construction 3 inches in thickness will save about 125 square feet of radiation (or 290 linear feet of 1¼-inch pipe) or from 3 to 4 tons of coal for heating per year for each 1000 square feet of roof area.

The following gives a comparison of tests in terms of B.t.u. transmitted per hour per degree difference in temperature through different thicknesses of gypsum and concrete:

Thickness (inches)	B. t, u. Gypsum	Concrete
0.250	0.667	0.780
.500	.575	.770
.750	.503	.757
.875	.476	.750
1.000	.455	.745
2.000	.314	.706
3.000	.242	.670
4.000	.196	.635

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Fireproofing

Gypsum also possesses a peculiar virtue as an insulating material for protecting columns and beams of wood or metal from the high temperatures that develop during a conflagration. This property grows out of the fact that the gypsum must be deprived of its water of crystallization before its temperature can be made to rise above that of its dehydration 105° F.) It has been proven by laboratory tests that a protective coat of two inches of gypsum will protect steel against the temperatures that develop in severe conflagrations.

Gypsum plaster board is one of the few forms of wall board on the market that has fire-resisting features. Its value in this connection is recognized by the Underwriters, and numerous State and Federal bureaus recommend the use of gypsum plaster board. Gypsum board itself will not burn even at high temperatures and is capable of withstanding great heat for a long time without breaking down. It thus presents an effective barrier to the spreading fire.

Plaster board does not shrink, expand, warp, or buckle, and, for all situations where a type of construction more flexible than a plastered surface is desired, it offers greater advantages than nearly any other form of construction material.

Gypsum blocks have received the full approval of the Underwriters' Laboratories for use in nonbearing partitions, stairways and elevator enclosures in fireproof building construction.

An important fireproofing feature of gypsum blocks is their freedom from expansion and contraction during great changes in temperature, and therefore they are the most suitable material for the covering of steel girders and beams. Tests have shown that gypsum blocks have 40 per cent greater resistance to heat conduction than other standard materials tested.

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